Floating Foundation System

Prepared for:

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1. INTRODUCTION

To conclude this three-stage program on the development of the floating foundation system, a final computer simulation scenario using the results obtained from the full scale test evaluation conducted in Phase 2 was undertaken.

The final design was then reviewed and the most effective method of installation was established.

To determine the effectiveness of the floating foundation system, the method of analysis used to represent actual in-situ conditions was critiqued.

Finally, conclusions and recommendations on the future role of this foundation system as an alternative construction technique in discontinuous permafrost were noted.

2. FINITE ELEMENT STATIC STRESS ANALYSIS FOR THE FLOATING FOUNDATION SYSTEM

The full scale testing on the floating pad frame established the maximum loading force prior to the start of permanent deformation. This information allowed the analysis of the foundation system under the two worst case scenarios using computer simulation.

The two test cases are outlined as follows:

Case 1: Loss of foundation support of two exterior float pads.

Case 2: Loss of foundation support of two interior float pads.

The full test program conducted by the Computer Aided Engineering Dept. at ORTECH International is listed in Appendix A.

However, the conclusions are listed as follows:

a) Loss of support of one corner float pad on each side of the frame leads to forces in some of the remaining pads to exceed the allowable design load by about 10%. This is probably acceptable based on the observation from the float compression test.

b) The system can sustain the losses of two inside float pads without overstressing the remaining units.

c) In both cases I and II, stresses in the one-ply beams exceed the allowable design stress.

3. FINAL FOUNDATION DESIGN AND INSTALLATION PROCEDURE

3.1 Foundation Design

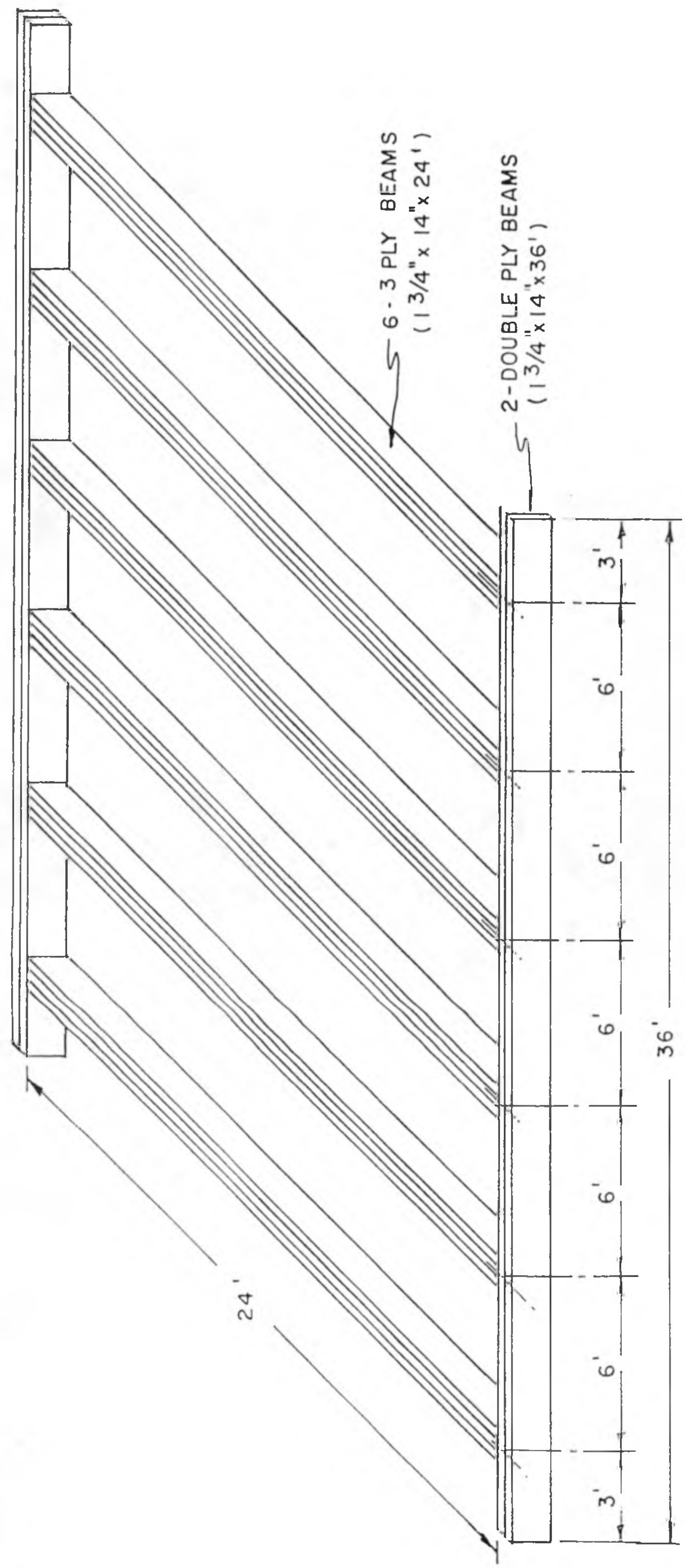
The initial floor plan which was designed in Phase 1 of this program was reviewed and modified according to the recommendations made in the computer analysis report (Appendix A).

The modified floor plan design (see drawing No. 1) now incorporates a double-ply beam as a header board. The maximum allowable design stress will increase to 5500 psi from 2750 psi. This design value now exceeds the stress generated in the two worst case scenarios.

The foundation plan (see drawing No. 2) and the floating pad frame with floats (see drawing No. 3) remains unchanged except for the inclusion of the extra header beam.

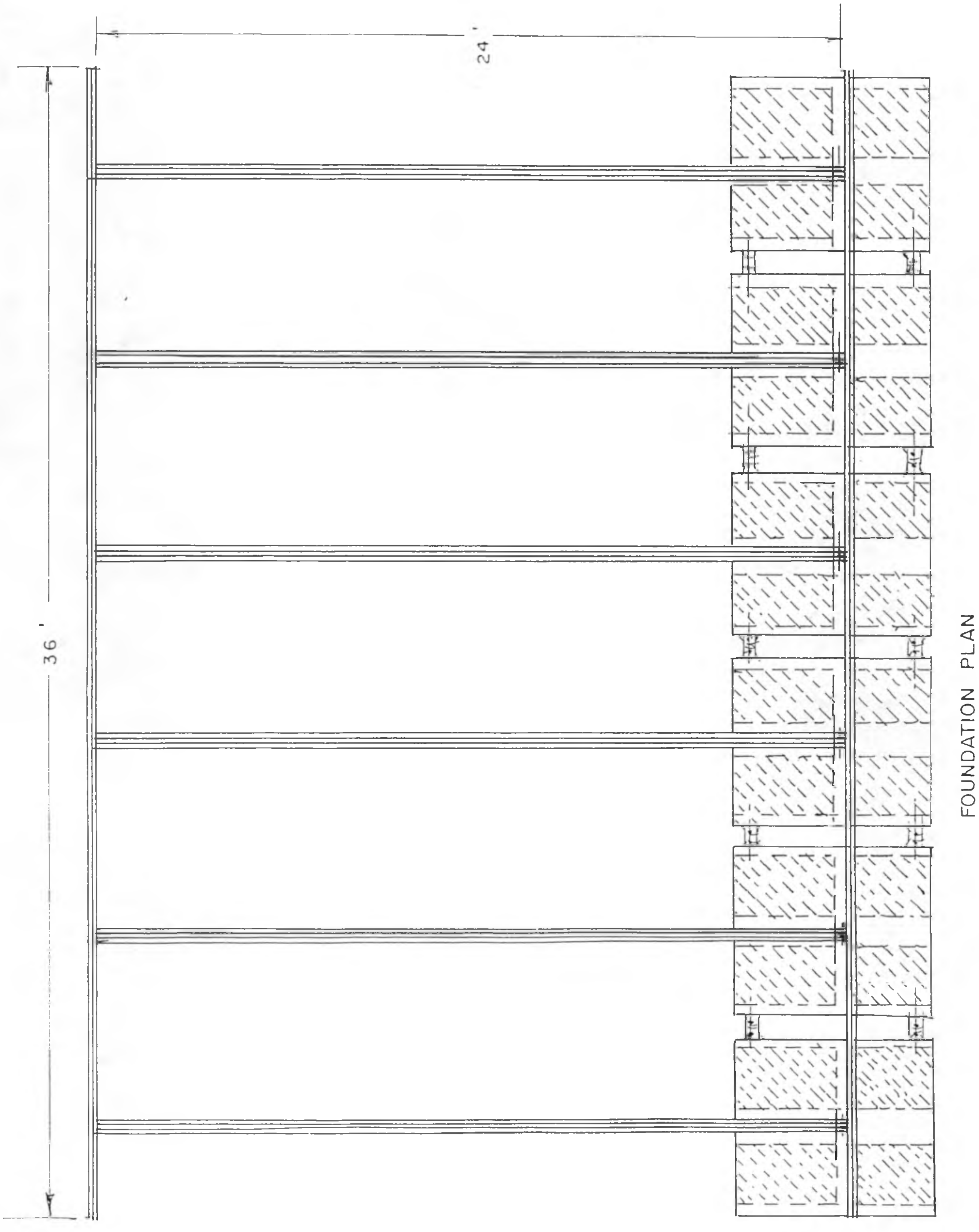
A conceptral view (see drawing No. 4) of how the floating foundation system would appear under a standard single storey family dwelling demonstrates the simplicity and compatibility of the system.

Drawing No. 1

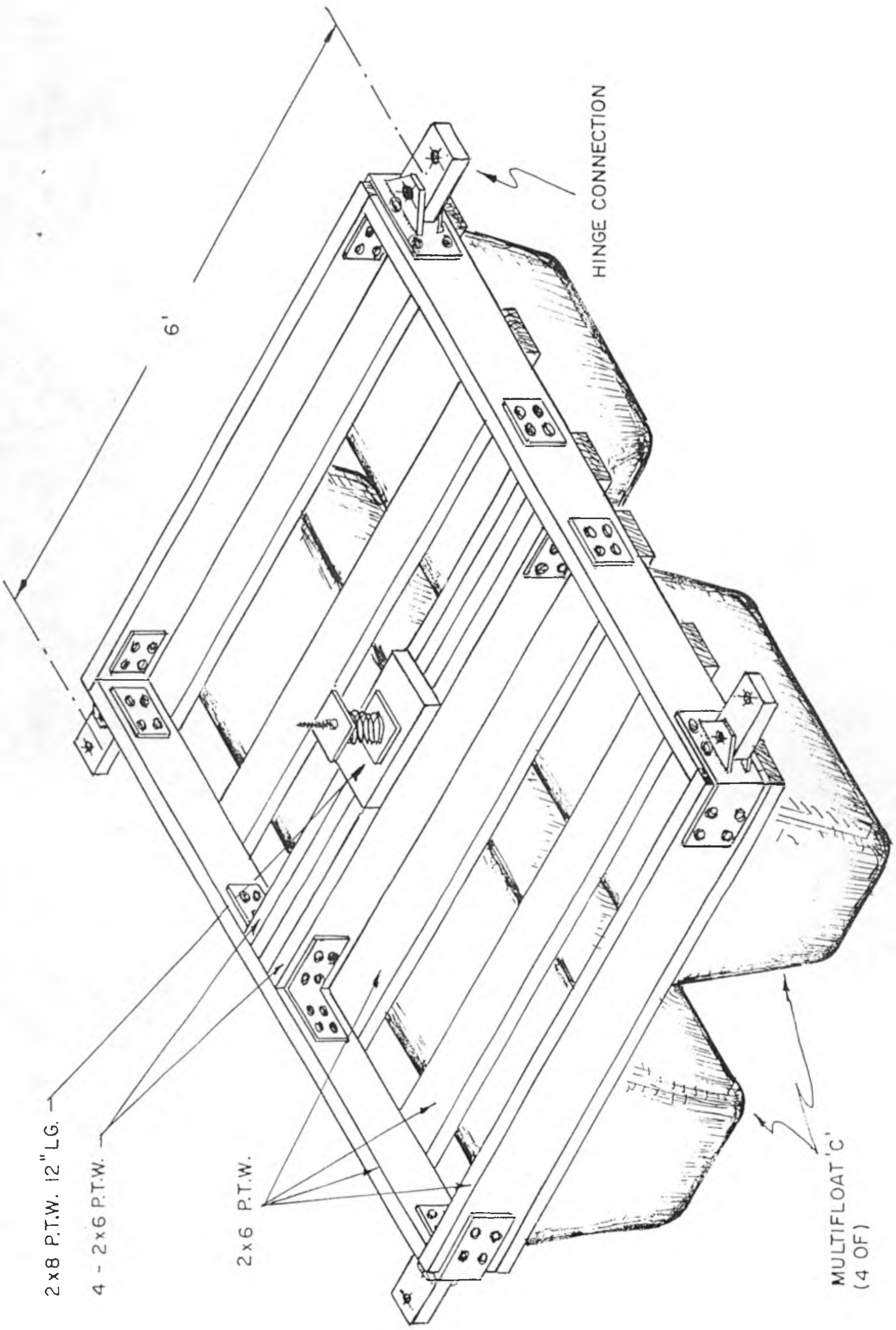


FLOOR PLAN

Drawing No. 2

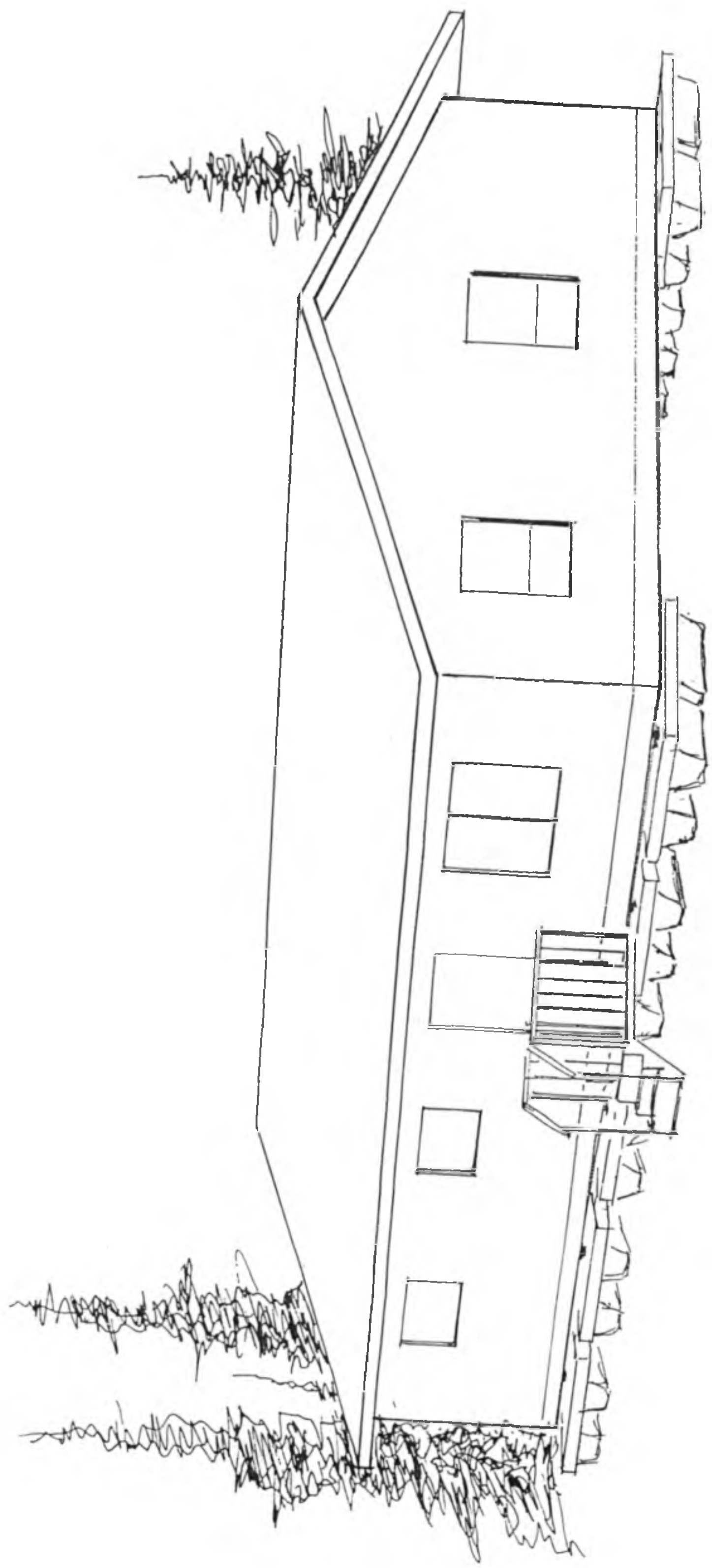


Drawing No. 3



FLOATING PAD FRAME WITH FLOATS

Drawing No. 4



3.2 Installation Procedure

The foundation system is designed specially to mimimize earthwork, be functional on soils with limited bearing capacity and in areas where gravel or clean fill is not available. The only criteria which has to be met is the soil surface should be approximately level. In most cases, if a construction site which is fairly level is chosen, no foundation preparation is necessary.

The floating pad frame can be constructed using only the basic tools (drill, wood saw, socket set and hammer) and unskilled labourers. Once all the floating pad frames with floats and springs have been constructed, they can be placed in the desired position on the surface of the soil at the construction site and connected with the elastomeric hinges.

The floor plan can be constructed as per normal building techniques on top of the foundation system. Once this has been accomplished, the construction of the house can proceed as per normal.

4.0 LIMITATIONS OF THE FULL SCALE TESTING AND COMPUTER SIMULATION PERFORMED

The full scale testing of the floating pad frame with floats successfully duplicated four adverse in-situ conditions. These conditions are as follows:

a) Vertical compression of frame with floats at room temperature.
b) Vertical compression of frame with floats after the system was conditioned for three days at sub zero temperatures.
c) Vertical compression of frame with only two floats touching the floor (simulation of end to end racking).
d) Vertical compression of frame with two parallel floats touching the floor (simulation of vertical twisting).

The individual pad frames with floats performed beyond design expectations in each test case. This is a good indication that the design will function adequately as a system under real conditions.

However, the whole system which includes a series of pad frames with floats connected to each other via an elastomeric hinge and connected to the house frame via springs was not physically tested according to the following parameters:

a) operation and maintenance of the whole system under long term loading patterns

b) Sensitivity of the entire system to freeze-thaw cycles, ice lenses and other environmental changes.

Even without the imposed budget constraint it would be difficult to reproduce these conditions in a laboratory. Hence, the computer simulation method was chosen as a logical means of going beyond the limiting physical testing yet remaining within the budget constraints.

The computer analysis was able to evaluate the whole system under calculated design loads, with different worse case scenarios such as the loss of certain support pads. The results generated provide useful information and partially addressed some of the concerns noted above.

Unfortunately, the remaining questions pertaining to long term durability, sensitivity of the springs to adjust to varying loading conditions and long term operation of the system were not and cannot be duplicated by either laboratory tests or by computer simulation.

5.0 CONCLUSION

Based on the assumptions made with respect to soil conditions, the required design parameters, test results and computer analysis, the floating foundation system performed beyond expectations and is quite suitable for discontinuous permafrost applications.

The combination of physical and computer analysis provided a complete and rigorous test program that fairly evaluated the foundation design to the limit of theoretical and laboratory analysis.

6.0 RECOMMENDATIONS

Since this floating foundation system has been investigated to the limit of theoretical and laboratory analysis, the next evaluation step should involve a long term (1-2 years) full scale in-situ investigation. This evaluation program will then be able to address the question of durability and sensitivity of the system. The successful completion of this field evaluation program will allow the implementation of this system for northern houses located within discontinuous permafrost zones.

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APPENDIX A

Computer Analysis

ORTECH

FINITE ELEMENT STATIC STRESS ANALYSIS FOR A FLOATING FOUNDATION SYSTEM (Part II)

A report for:

Building Performance Centre
ORTECH International

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1.0 INTRODUCTION

This is a continuation of the work completed by the Computer Aided Engineering Group at ORTECH International on a floating foundation system analysis for the Building Performance Centre of ORTECH. The system consists of a glue-laminated frame (24' x 36') supported by 12 springs resting on float pads. In the previously completed work, the effects of partial loss of spring supports were not analysed.

2.0 OBJECTIVE

The objective of this work is to study the effects of some losses in foundation support on the structural stability of the system.

3.0 FINITE ELEMENT MODEL

The finite element model developed in the previous work was used in this analysis. The single ply beams (1-3/4" x 14") were constructed of linear shell elements. The 3-ply beams (5-1/4" x 14") were constructed of linear solid elements. The springs were modelled using linear node-to-node translational spring elements.

4.0 MATERIAL PROPERTIES

Properties of the pressure treated timber for the beams are as follows:

a) Modules of elasticity (E) = 2×10^6 psi
b) Allowable flexural for 14" deep beam = 2750 psi

Mechanical properties of the floats are not available. However, a float pad which consists of four individual floats fastened to a small wood frame was tested. It was compressed up to a load of about 20,000 lbs. The elastic and permanent deformation observed was reported to be insignificant. In this study, the design load capacity for the float pads was taken as 20,000 lbs.

5.0 LOADS AND RESTRAINTS

A floor load of 100 psf was selected by the Building Performance Centre for this analysis. These loads were distributed as face pressures on some very soft shell elements placed on the top side of the wood frame.

Two restraint sets were used in this finite element analysis. In Case I, the lower nodes of the springs were restrained in all three translational directions except for two diagonally opposite springs. This case simulates the conditions for the loss of foundation support of two exterior float pads. Restraints and loads for Case I is shown in Figure 1. In Case II, there are two inside float pads that lose ground contact. These two pads are at the different sides of the frame. Figure 2 shows the loads and restraints of Case II.

6.0 FINITE ELEMENT ANALYSIS

The finite element model was solved in MODEL Solution, a finite element static and dynamic solver in the I-DEAS software of Structural Dynamics Research Corporation (SDRC). The two restraint sets were used in the runs.

7.0 FINITE ELEMENT RESULTS

Results from the finite element analysis are presented in Figures 3 to 6. They are also summarized as follows:

	Longest Max. Principal Stress (psi)	Max. Foundation Reaction (lbs)	Max. Vertical Displacement (inches)
Case I	4910 (2750)*	22,256 (20,000)*	12.20
Case II	3790 (2750)*	10,539 (20,000)*	6.07

* Allowable design values.

8.0 CONCLUSIONS

a) Loss of support of one corner float pad on each side of the frame leads to forces in some of the remaining pads to exceed the design allowable load by about 10%. This is probably acceptable based on the observation from the float compression test.

b) The system can sustain the losses of two inside float pads without overstressing the remaining units.

c) In both cases I and II, stresses in the one-ply beams exceed the allowable design stress.

9.0 RECOMMENDATIONS

If the system is designed to carry the full design loads with the loss of support from either a corner or inside float pad at each side of the frame, the one-ply side beams need to be strengthened to reduce the stresses below the allowable design value.

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FIGURES

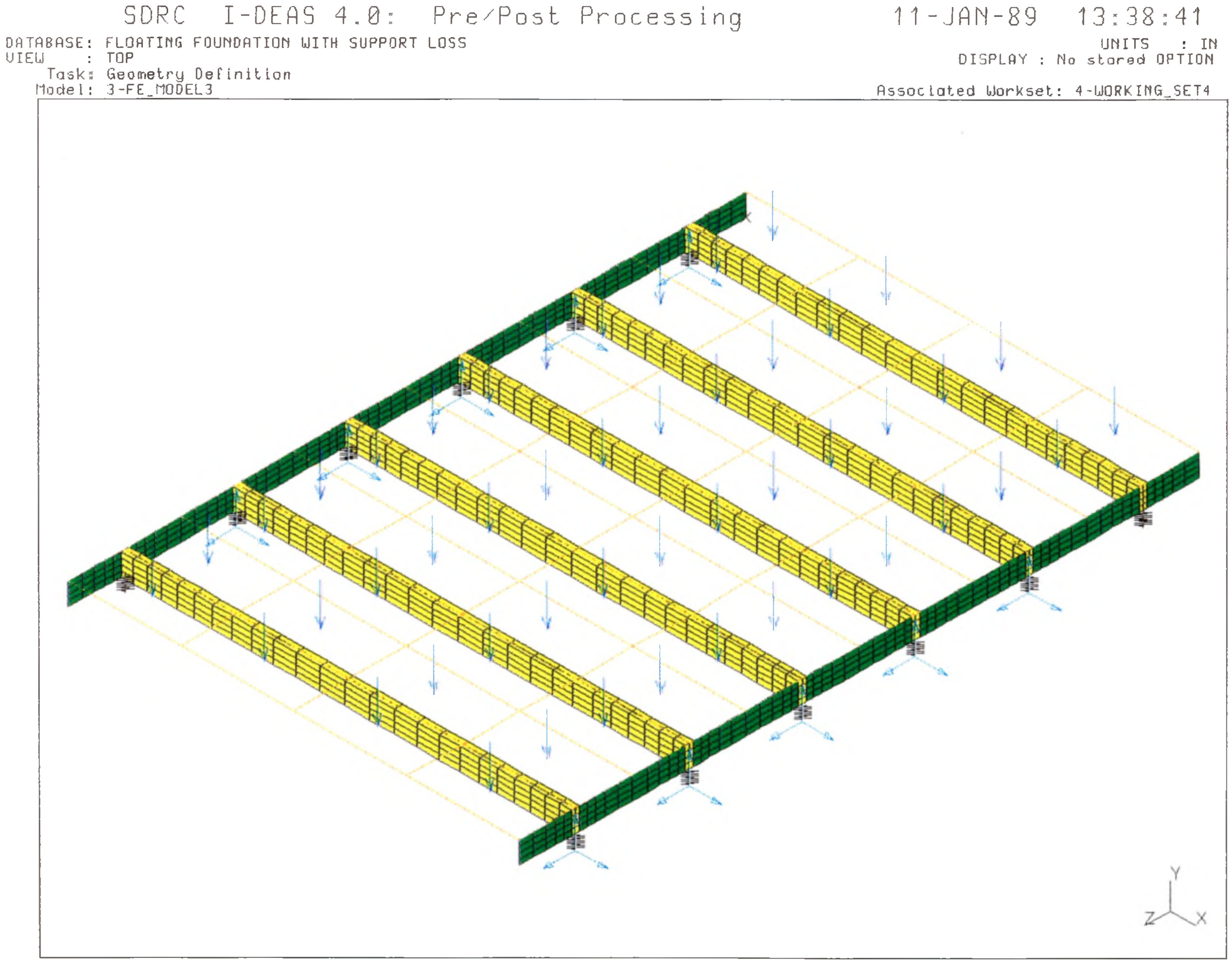

Figure 1: Finite Element Loads and Restraints for Case I

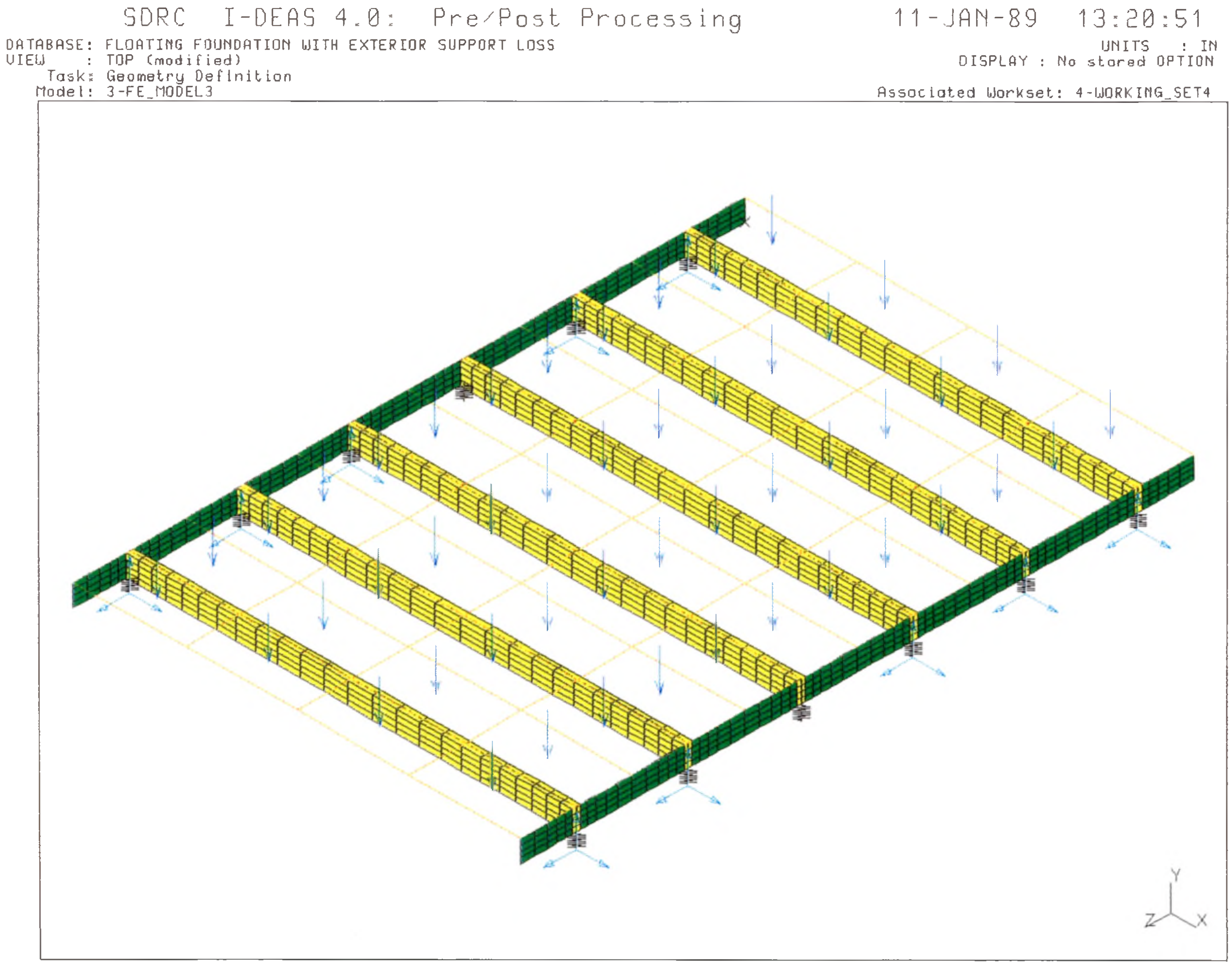

Figure 2: Finite Element Loads and Restraints for Case II

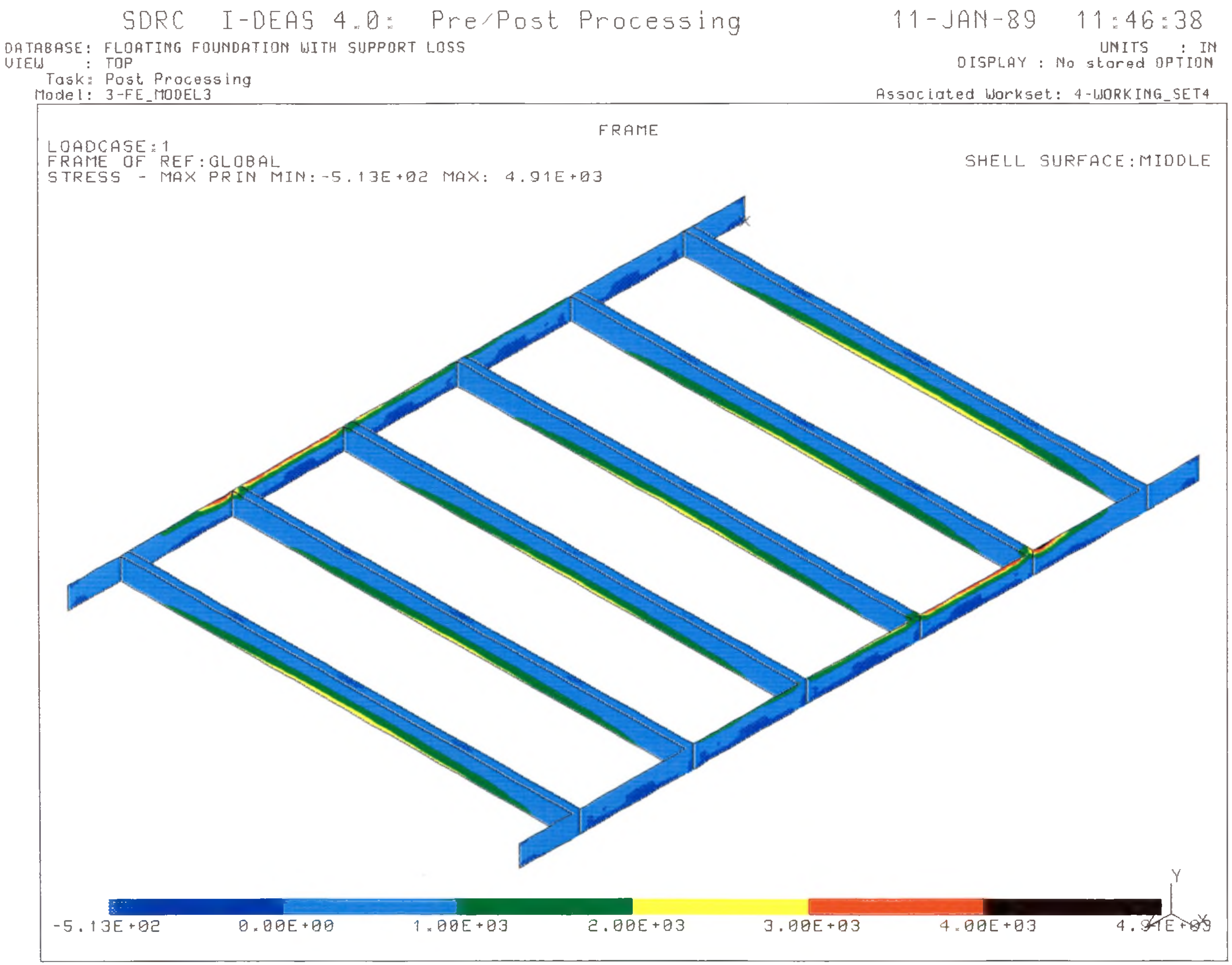

Figure 3: Maximum Principal Stress Contours on the Floating Foundation Frame with Corner Support Loss, Case I (top isometric view)

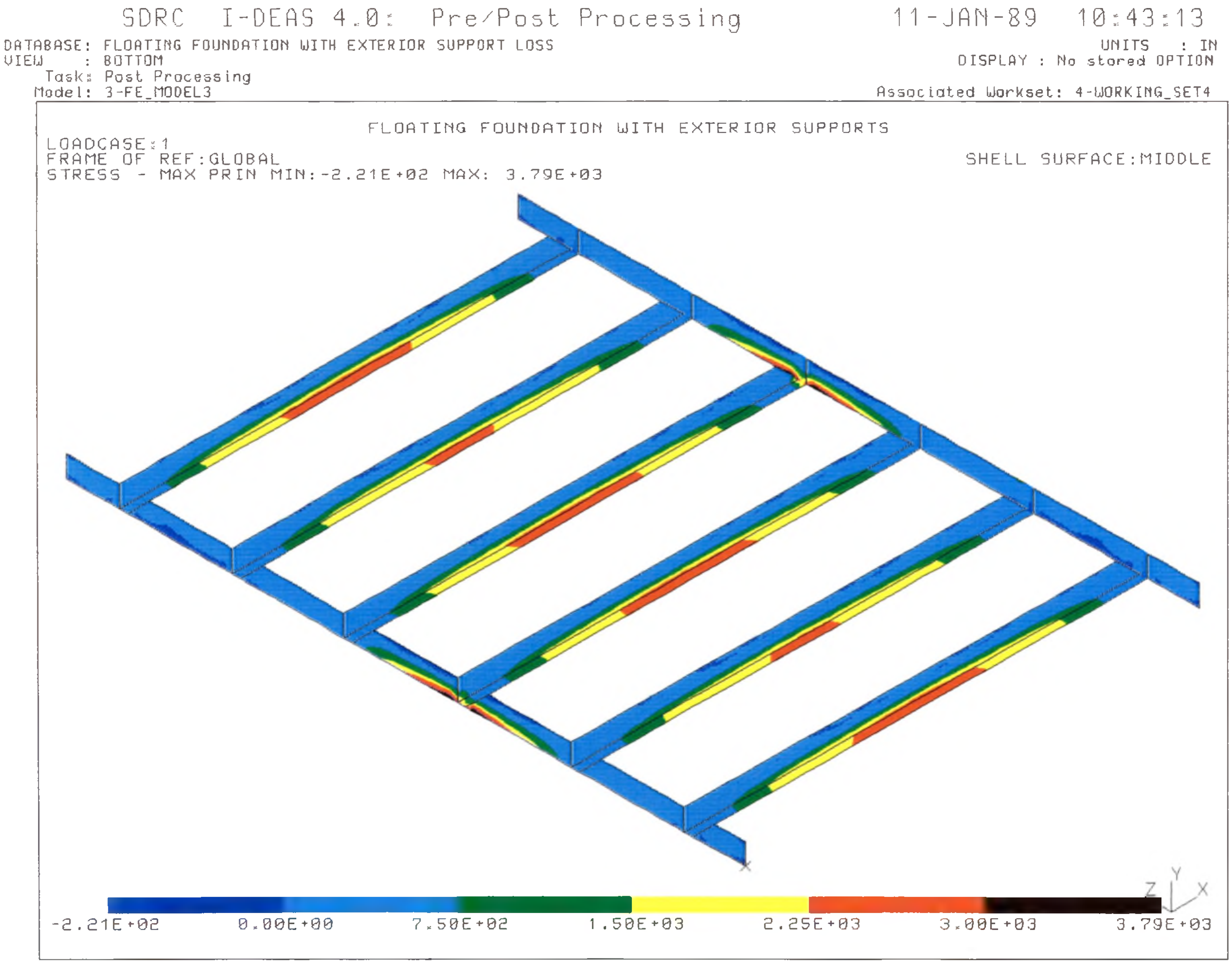

Figure 4: Maximum Principal Stress Contours on the Floating Foundation Frame with Inside Support Loss, Case II (bottom isometric view)

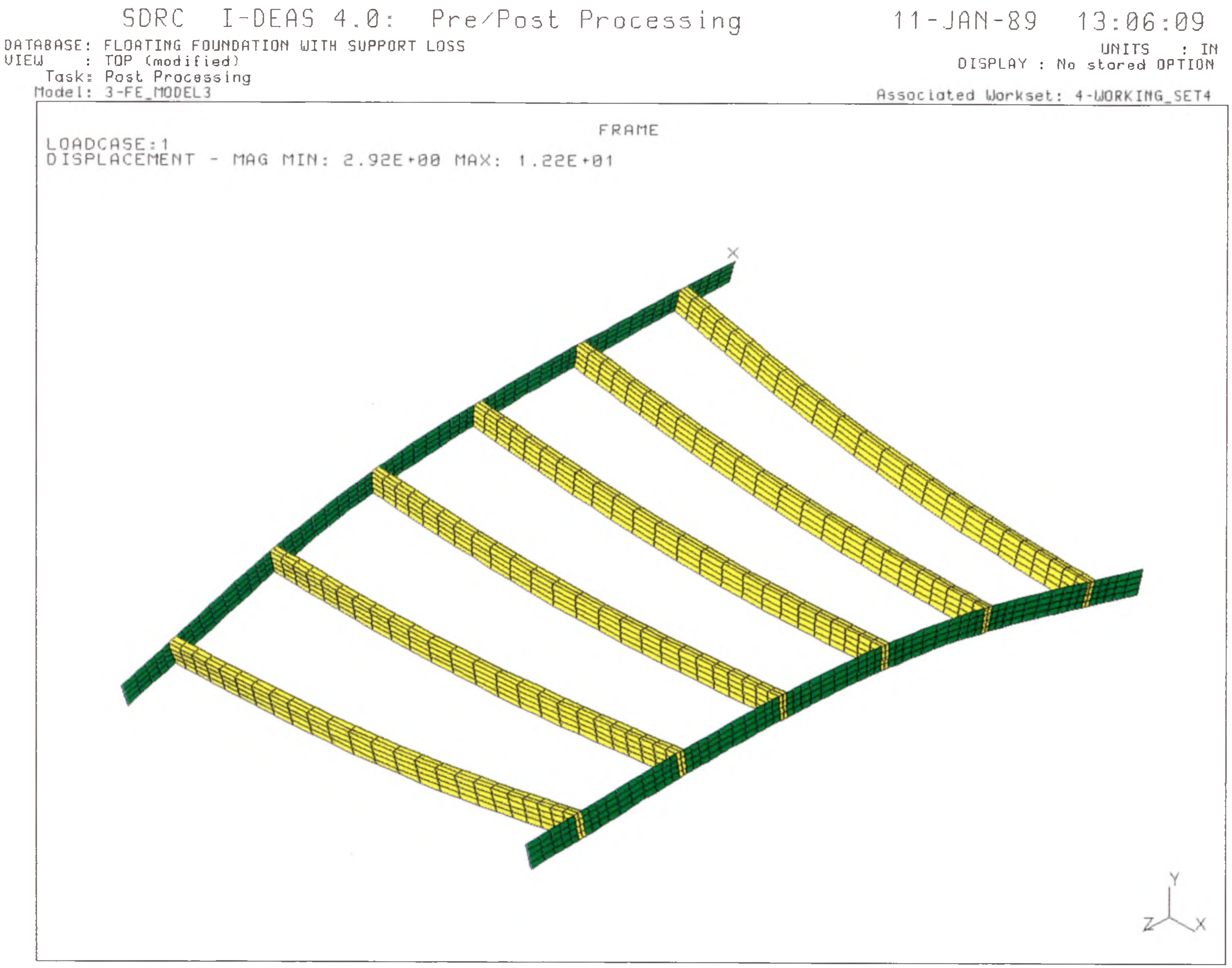

Figure 5: Exaggerated Deformed Geometry of the Floating Foundation Frame (Case I)

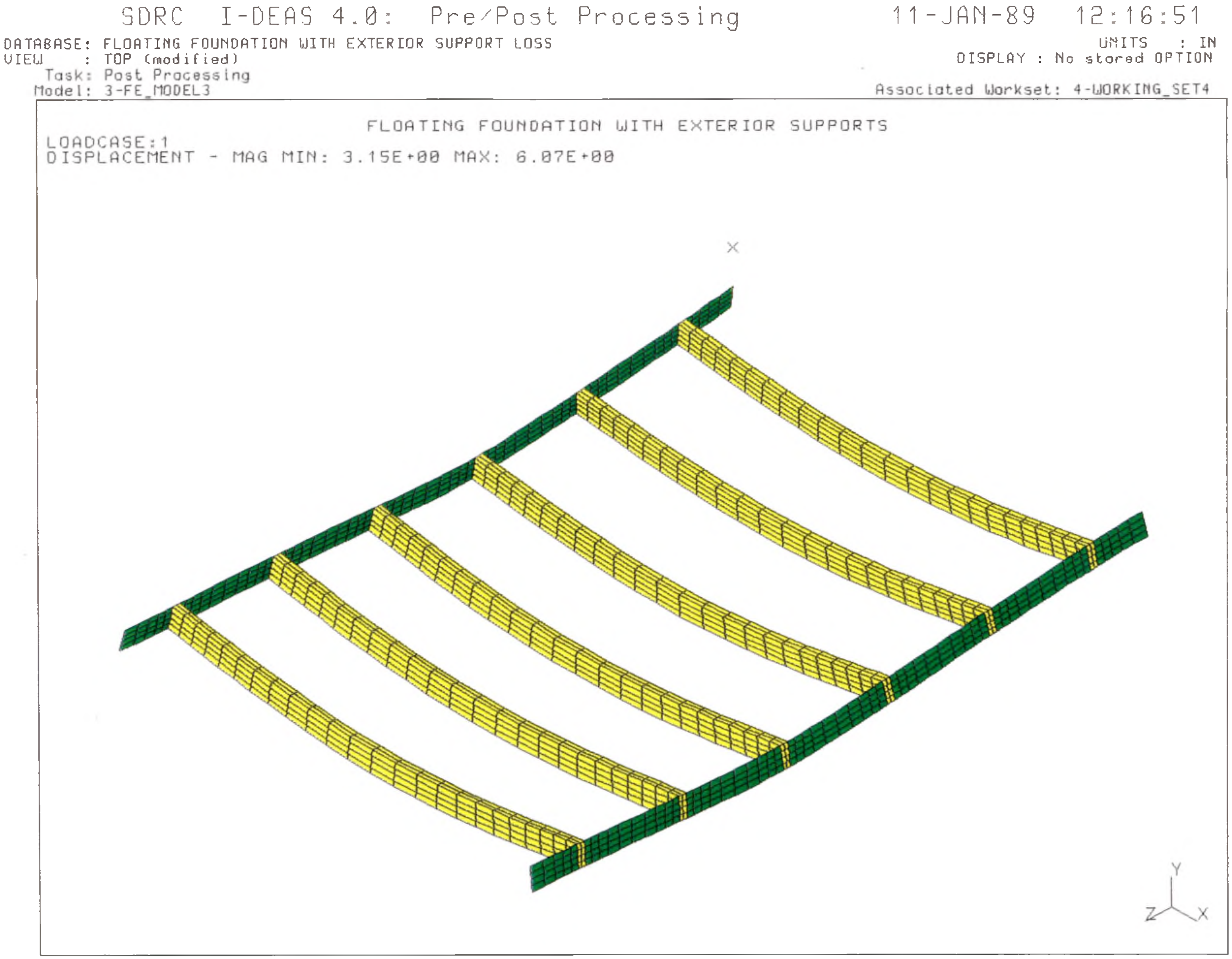

Figure 6: Exaggerated Deformed Geometry of the Floating Foundation Frame (Case II)